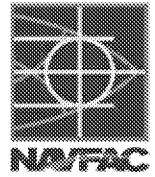
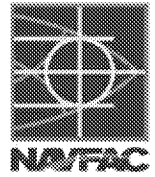


Task #2: Investigate the LNAPL



- **Potential Methods for Detecting Non-Aqueous Phase Liquid (NAPL) in the Subsurface:**
 - 1) **Borings and Groundwater Monitoring Wells**
 - 2) **Laser Induced Fluorescence Tools**
 - 3) **Membrane Interface Probe Dye Impregnated Liners**
 - 4) **Soil Gas Survey**
 - 5) **Geophysical Methods**
 - a) Resistivity
 - b) Seismic
 - c) Spontaneous Potential
 - d) Gravity & Magnetic
 - e) Induced Polarization
 - f) Ground Penetrating Radar
 - g) Magnetic Resonance
 - h) Electromagnetic

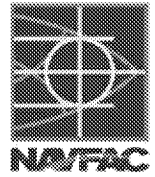
Task #2: Investigate the LNAPL



1. Borings and Groundwater Monitoring Wells

- Effective at confirming the presence of NAPL when locations are known or plume is widespread
- Allows determination of other subsurface properties for modeling and remediation
- No practical depth limitation
- May allow sampling of NAPL for laboratory analysis.
- However
 - Only detects NAPL in borehole – can be very “hit or miss” in heterogeneous and in fractured rock formations such as Red Hill
 - Can be very expensive to complete an investigation
 - Requires relatively level and stable drilling platform
 - Can create preferential pathways for vertical migration to the groundwater
- **Conclusion: Not recommended for implementation; evaluation of method to be included in Work Plan/SOW**

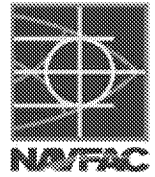
Task #2: Investigate the LNAPL



2. Laser Induced Fluorescence Tools (e.g., UVOST)

- Effective at directly detecting petroleum NAPL in the sidewalls of a borehole
- However
 - Requires direct push rig to advance the tool
 - Ineffective in bedrock formations
 - Does not detect dissolved phase contamination
 - Only detects NAPL in borehole – can be very “hit or miss” in heterogeneous and in fractured rock formations such as Red Hill
- **Conclusion: Not recommended for implementation; evaluation of method to be included in Work Plan/SOW**

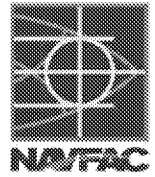
Task #2: Investigate the LNAPL



3. Membrane Interface Probe (MIP)

- Effective at delineating dissolved-phase petroleum contamination
- The presence/absence of NAPL can be inferred based on the MIP data
- MIP is most effective in detecting organic chemicals with relatively low boiling points (i.e., less than 100°C)
- However
 - Requires direct-push drill rig to advance the MIP
 - Ineffective in bedrock formations
 - Detector or probe can become damaged if driven through NAPL
 - Only detects NAPL in borehole – can be very “hit or miss” in heterogeneous and in fractured rock formations such as Red Hill
 - The identified COPCs appear to have a boiling point over 100°C
- **Conclusion: Not recommended for implementation; evaluation of method to be included in Work Plan/SOW**

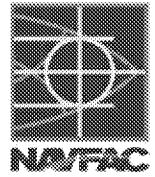
Task #2: Investigate the LNAPL



4. Dye Impregnated Liner (FLUTe)

- Effective at detecting NAPL presence and depth in the sidewalls of a borehole
- Can be used in bedrock
- However
 - Liner requires small diameter borehole
 - Potentially expensive as numerous boreholes would likely need to be drilled if using for delineation purposes
 - Only detects NAPL in borehole – can be very “hit or miss” in heterogeneous and in fractured rock formations such as Red Hill
- **Conclusion: Not recommended for implementation; evaluation of method to be included in Work Plan/SOW**

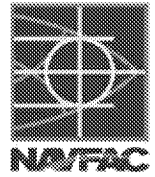
Task #2: Investigate the LNAPL



5. Soil Gas Survey (Passive)

- Effective at detecting lighter fuels such as gasoline
- Minimally invasive (typically installed 5-10 feet bgs)
- Can theoretically be used in all geologic formations
- However
 - Less effective for middle distillates and heavier fuels such as those stored at Red Hill
 - Effectiveness decreases with depth of NAPL
- **Conclusion: Not recommended for implementation; evaluation of method to be included in Work Plan/SOW**

Task #2: Investigate the LNAPL



6. Geophysical Surveys

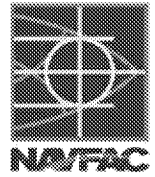
a) Resistivity

- Electrical resistivity tomography measures resistivity of formations, sensitive to pore fluids such as NAPL
- Can be collected as 3-D data and through time to document changes
- Minimally invasive to install electrodes
- Depth of investigation is adjustable
- Useful for leak detection, plume mapping, and hydraulic characterization
- **Conclusion: Potentially feasible; evaluation of method to be included in Work Plan/SOW**

b) Seismic

- Measures acoustic velocity and includes reflection and refraction methods
- Most commonly used for mapping bedrock, including faults/fractures at various depths
- Can detect groundwater surface, perched groundwater, and voids
- Not generally used for environmental investigations
- Effectiveness at detecting NAPL not well-documented
- **Conclusion: Not recommended for implementation; evaluation of method to be included in Work Plan/SOW**

Task #2: Investigate the LNAPL



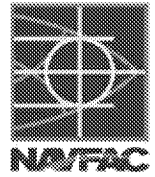
c) Spontaneous Potential (SP)

- Measures the natural voltage difference between two points
- Can identify where water is flowing in the subsurface
- Used primarily for investigating the integrity of earthen dams/dikes
- Effectiveness at detecting NAPL not well-documented
- **Conclusion: Not recommended for implementation; evaluation of method to be included in Work Plan/SOW**

d) Gravity & Magnetic

- Measures changes in either the gravity field or magnetic field (natural or induced)
- Can be quickly and easily performed over large areas
- Used in the exploration of large ore bodies and sometimes petroleum exploration, usually to identify smaller areas of interest
- Effectiveness at detecting NAPL not well-documented
- **Conclusion: Not recommended for implementation; evaluation of method to be included in Work Plan/SOW**

Task #2: Investigate the LNAPL



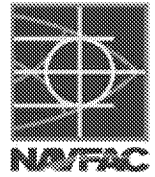
e) Induced Polarization (IP)

- Secondary resistivity method that measures the charge storage capacity of materials
- Can use same equipment as resistivity survey
- Used to investigate landfills and petroleum NAPLs, and map lithologies
- Can be combined with electrical resistivity tomography
- Further research required to determine whether this is likely to be effective at Red Hill
- **Conclusion: Potentially feasible; evaluation of method to be included in Work Plan/SOW**

f) Ground Penetrating Radar (GPR)

- High resolution acoustic method uses frequencies from 10-1000 MHz
- Shallow depth of investigation (< 20 feet)
- Used to image shallow structures such as tanks, utilities, and voids
- **Conclusion: Not recommended for implementation; evaluation of method to be included in Work Plan/SOW**

Task #2: Investigate the LNAPL



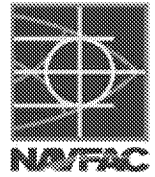
g) Magnetic Resonance

- Direct detection of groundwater
- Used to estimate depth to groundwater, permeability, and water content
- Sensitive to interference from power lines
- Poorly suited for volcanic rock terrains
- **Conclusion: Not recommended for implementation; evaluation of method to be included in Work Plan/SOW**

h) Electromagnetic (EM)

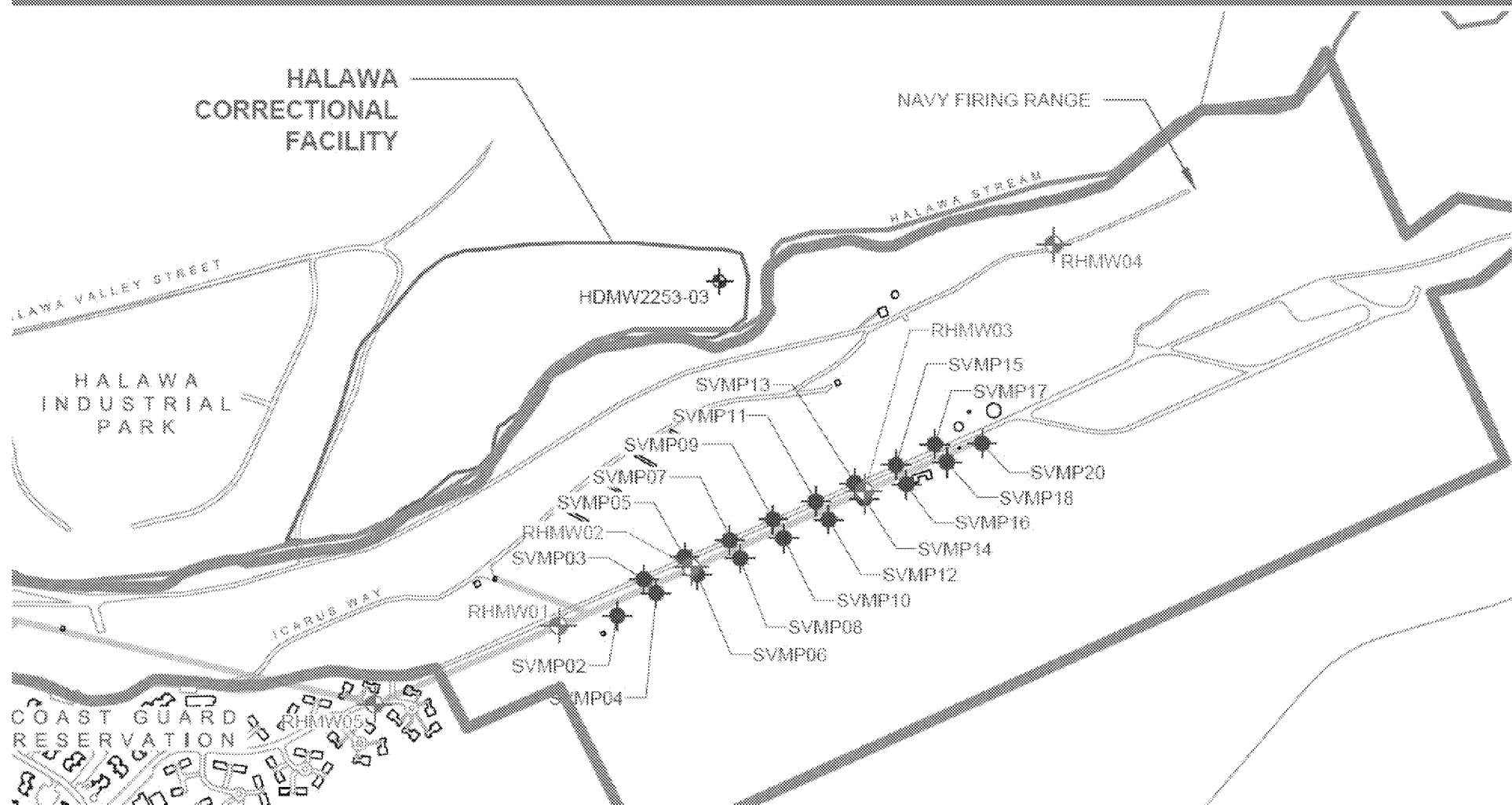
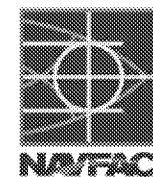
- Multiple EM methods are available
- Used to map landfills and other conductive soil and groundwater contamination, characterize subsurface hydrogeology, map conductive faults/fracture planes, and map geologic structures
- Further research required to determine whether this is likely to be effective at Red Hill
- **Conclusion: Potentially feasible; evaluation of method to be included in Work Plan/SOW**

Task #2: Soil Vapor Considerations

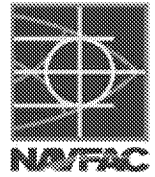


- **Soil Vapor Sampling Monitoring Analysis (2010)**
 - a) **Vapor sampling at soil vapor monitoring points (SVMP) under active fuel tanks at that time**
 - SV02, SV03, SV06, SV11, SV14, and SV17
 - BTEX and TPH
 - b) **Evaluate if soil vapor concentrations measured during the monthly rounds are indicative of a new fuel release**
 - Correlated PID measurements with analytical TPH data
 - Established three benchmark concentrations via field measurements and phase partitioning calculations
 - Modeled diffusion as the critical transport process for subsurface vapor to calculate temporal vapor concentration increases at set distances (10, 50, 100 feet)
 - Relationship to rain events

Task #2: Soil Vapor Considerations



Task #2: Soil Vapor Considerations



- **Soil Vapor Sampling Monitoring Analysis Letter Report (2010)**

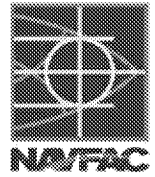
- a) **Conclusions**

- Low vapor concentrations measured and apparent mobilization of vapors due to water recharge (i.e., rain events) indicate current source of vapors observed were residual or of a small release
 - Indications of a minor release less likely due to the general trend of vapor concentrations (downward trend)
 - Soil vapor readings taken on a regular basis (i.e., monthly) provides an “excellent indicator of potential fuel releases”
 - Diffusion calculations show vapors are very mobile making detection of a leak probably within a few weeks following a small release

- b) **Recommendations**

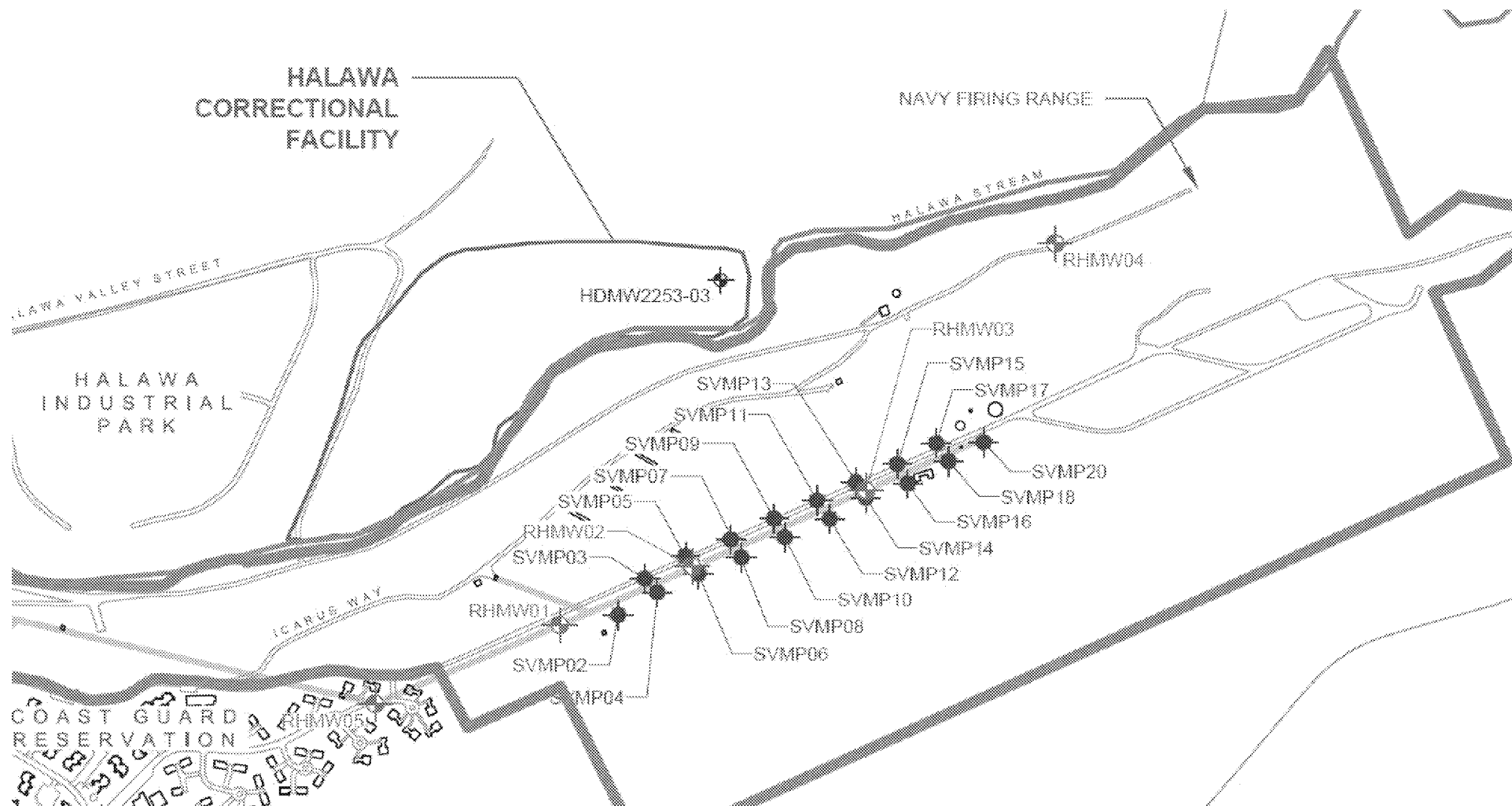
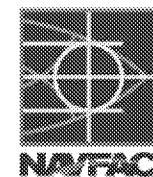
- Soil vapor concentrations approaching 280 ppmv in SVMPs beneath the tanks containing jet fuels warrant special attention
 - Vapor concentrations approaching 14 ppmv in SVMPs beneath tanks containing diesel fuel also warrant special attention
 - Validating/Updating maximum soil vapor calculations
 - Partitioning studies to develop a fingerprint baseline to differentiate between fresh and weathered contaminants

Soil Vapor Considerations

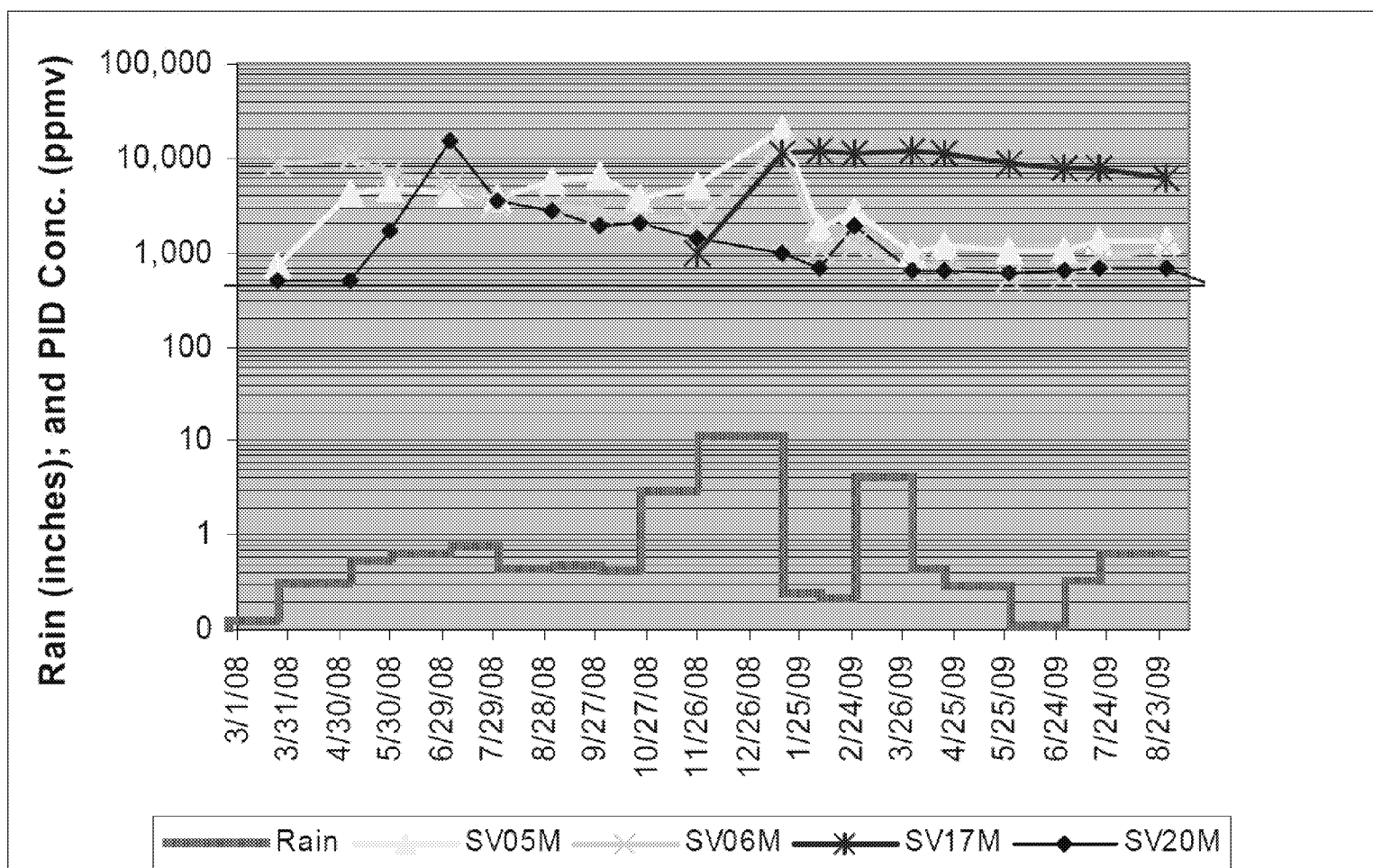


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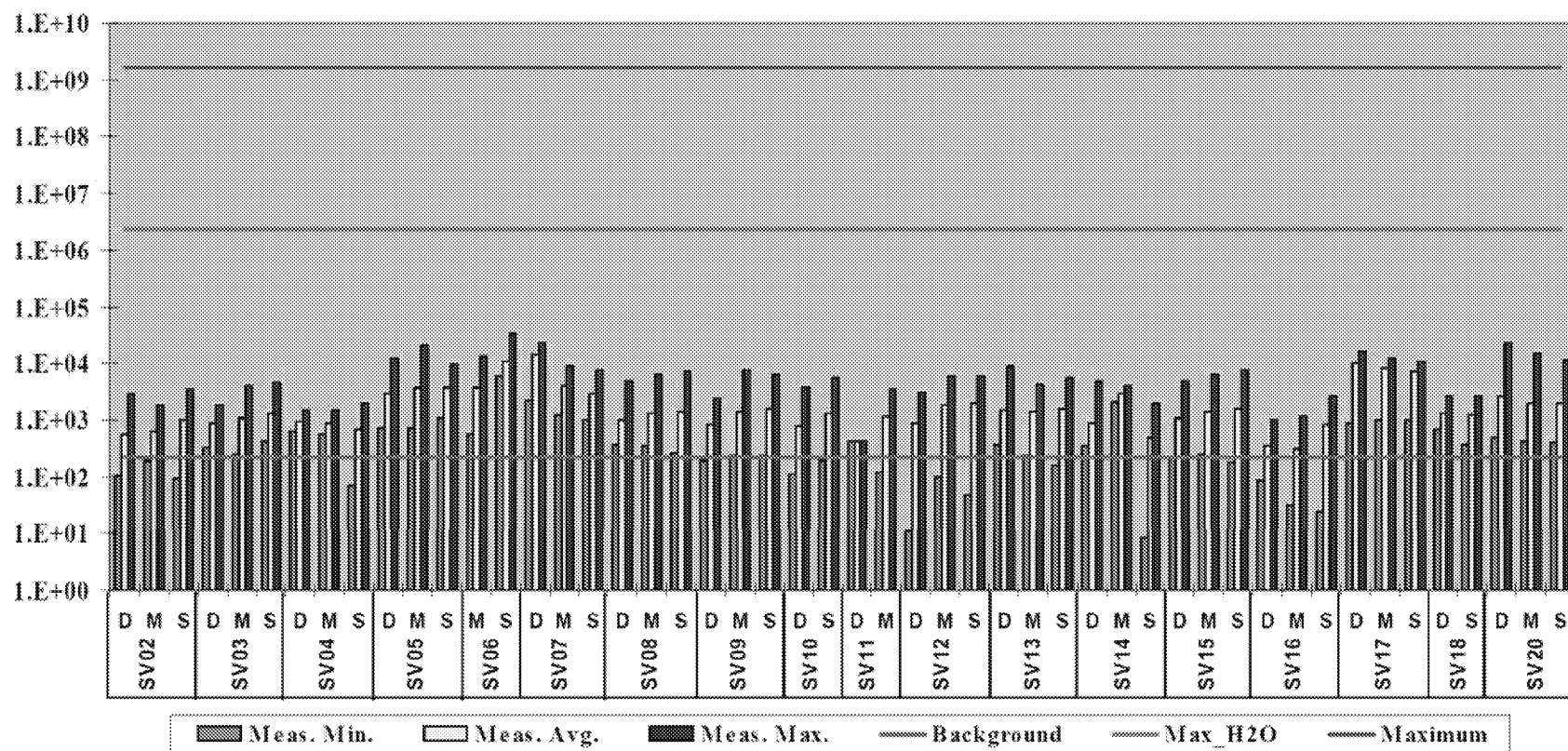
Soil Vapor Considerations



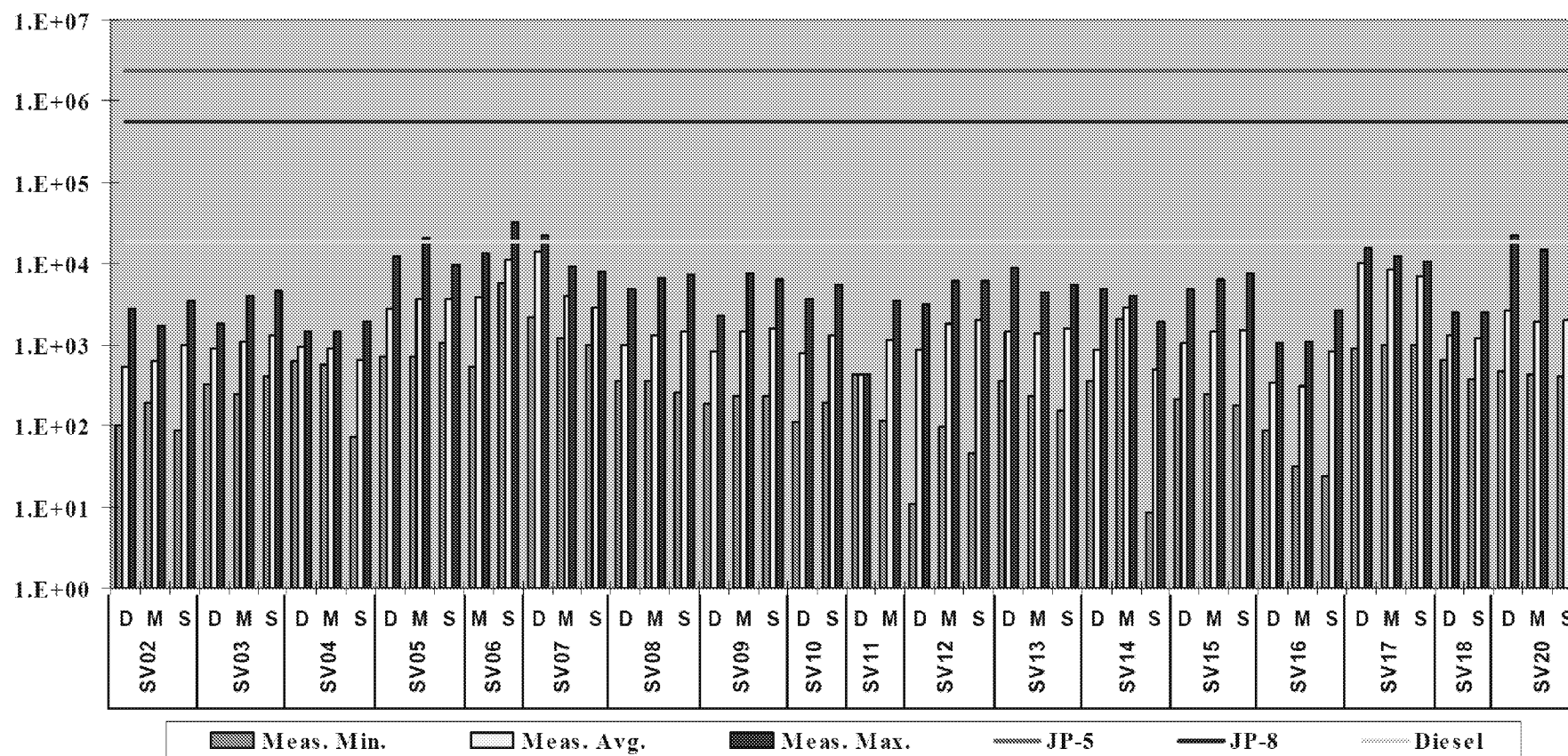
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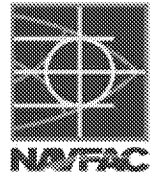
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Soil Vapor Considerations



Soil Vapor Considerations



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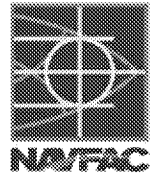
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Soil Vapor Considerations



- **Update Evaluation of Soil Vapor Concentration Trends**
 - a) **Determine if sampling frequency is still sufficient for detecting a release**
 - Re-evaluating the feasibility of improving the soil vapor monitoring program
 - b) **Confirm whether the benchmark PID concentrations recommended in the 2010 report are still sufficient as field screening levels to use for release detection**

